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**Abstract:** We report the case of a 40-year-old right-handed German-speaking man who presented with ischemic stroke in the territories of the right superior cerebellar artery and posterior inferior cerebellar artery. The objective of the present study was to investigate the consequences of this cerebellar damage with regard to higher cognitive functions. On admission to the stroke unit, the patient presented with dysarthria, right-sided appendicular ataxia, gait ataxia, and right-sided horizontal nystagmus (National Institutes of Health Stroke Scale, NIHSS, score 4). When examined 10 days after his stroke using a set of neuropsychological tests, he showed a marked deficit in the ability to remember when and in which context he had previously encountered verbal material. This aspect of memory, so-called 'source memory', is known to be mediated mainly by frontal and medial temporal structures. The present case suggests the existence of a strong functional connectivity between cerebellum and cortical regions underlying specific memory processes.

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# Cerebellum and Source Memory

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## Key Words

Cerebellar cognition • Cognitive impairment • Memory •  
Magnetic resonance imaging • Neuropsychology •  
Stroke unit

## Abstract

We report the case of a 40-year-old right-handed German-speaking man who presented with ischemic stroke in the territories of the right superior cerebellar artery and posterior inferior cerebellar artery. The objective of the present study was to investigate the consequences of this cerebellar damage with regard to higher cognitive functions. On admission to the stroke unit, the patient presented with dysarthria, right-sided appendicular ataxia, gait ataxia, and right-sided horizontal nystagmus (National Institutes of Health Stroke Scale, NIHSS, score 4). When examined 10 days after his stroke using a set of neuropsychological tests, he showed a marked deficit in the ability to remember when and in which context he had previously encountered verbal material. This aspect of memory, so-called ‘source memory’, is known to be mediated mainly by frontal and medial temporal structures. The present case suggests the existence of a strong functional connectivity between cerebellum and cortical regions underlying specific memory processes.

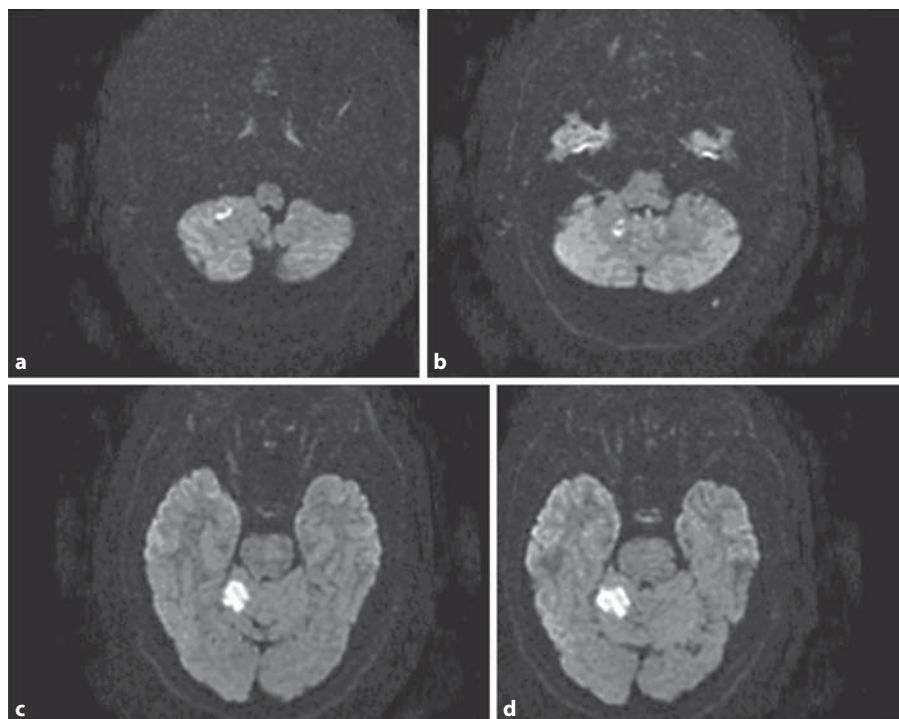
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## Introduction

Over the past two decades neuroimaging and clinical studies have demonstrated cerebellar involvement in higher cognitive functions.

Patients with cerebellar lesions may present with impairments of nonmotor functions such as language [1], verbal fluency [2], visuospatial skills [3] and working memory, in particular in the learning and in the recall phase of verbal information [4]. Such observations suggest a functional connectivity between different parts of the cerebellum and the cerebral cortex [5], in particular with the frontal lobes, involved in social behavior, executive functions, planning, language control and working memory. The frontal lobes also play a critical role in the retrieval of source, the capacity to remember ‘when’, ‘where’ and ‘in which context’ a memory information has been learned [6, 7]. Furthermore, besides frontal structures, many studies suggest the involvement of medial temporal lobe subregions in recognition performance, some of these mediating human source recollection ability [8].

Many studies documented a relationship between frontal lobe functioning and source recall ability [9]. Patients with frontal lobe lesions often show a diminished performance in tasks requiring the recall of the context of an episodic memory [10]. Accordingly, functional magnetic resonance imaging (MRI) studies emphasize that source memory relies on the frontal lobe [11].



**Fig. 1.** Diffusion-weighted imaging with areas of restricted diffusion indicating acute ischemia. Ischemia of the right caudal cerebellar hemisphere and dentate nucleus (territory of the posterior inferior cerebellar artery; **a, b**) and the anterior lobe of the superior right cerebellar hemisphere (right superior cerebellar artery; **c, d**).

## Patient and Methods

### Patient

This 40-year-old right-handed man was admitted to our stroke unit following a car accident. Neurological examination revealed dysarthria, right-sided appendicular ataxia, gait ataxia, and right-sided horizontal nystagmus (National Institutes of Health Stroke Scale, NIHSS, score 4). After exclusion of intracerebral hemorrhage on initial computed tomography scan of the brain, intravenous thrombolysis with recombinant tissue plasminogen activator was performed 144 min after symptom onset. MRI of the brain was performed 24 h after admission and showed acute ischemic lesions in the vascular territories of the right posterior inferior and right superior cerebellar arteries (fig. 1); there were no extracerebellar lesions in the posterior circulation. Stroke etiology remained unclear after extended diagnostic workup, which revealed normal results: extra- and intracranial duplex sonography, computed tomography and MR angiography of the neck and brain, fat-suppressed MRI of the neck for exclusion of artery dissections, transesophageal echocardiography and 48-hour Holter electrocardiography. Electroencephalography was normal suggesting that epileptiform discharges caused by the ischemic lesions did not contribute to the patient's symptoms.

### Methods

To investigate cognitive functions, we applied a set of various neuropsychological tests. Results were compared to an age-matched reference population and z-scores were calculated using normative values. Left-hemisphere language dominance was ensured by a standard lateralized tachistoscopic lexical decision task [12].

For verbal learning and retrieval, a regularly applied and well-validated memory test (VLMT, revised German version) was used [13]. In this test, a list of 15 words is presented in 5 consecutive learning runs. An interference list of 15 new words is then read and immediate recall is tested. Thereafter, the first list of words must be recalled and again after 30 min. Since the patient unexpectedly showed signs of source memory deficit during the verbal learning trials (i.e. an increased number of confabulations and perseverations), we immediately modified the recognition part of the VLMT during the neuropsychological examination. This part of the test has therefore not been validated before.

To evaluate the patient's verbal source and recognition memory capacity, selected words from those he had produced during the verbal fluency tasks were mixed among the words of the VLMT learning lists and were orally presented along with entirely novel distractor words. The patient was asked to decide whether a read word was new, from the original list, the interference list, or whether it was a self-generated word.

## Results

The patient achieved average performance in measures of information processing speed, divided attention, visuoconstructive ability, concept finding, and category fluency. A slight performance reduction was found in verbal phonematic fluency ( $z = -1.26$ ) and in verbal (digit span backward;  $z = -1.02$ ) and visual (visual span back-

ward;  $z = -1.32$ ) working memory. The results in the VLMT task showed that verbal learning ( $z = -2.34$ ), verbal delayed recall ( $z = -2.97$ ) and verbal recognition ( $z = -2.13$ ) were severely impaired. The numbers of words recovered during the 5 learning runs out of 15 words in total were 7, 6, 7, 6 and 8. Four words were recovered after 30 min. Notably, the patient exhibited an especially marked deficit in the recognition of previously self-generated words: only 4 of the 13 presented words were recognized as self-generated. Together with a low recognition rate for words from the interference list (7 recognized out of 11), this reflects a dramatic deficit in the ability to remember when and in what context correctly recognized items had been learned (source memory). Conversely, figural learning and recall (Rey 15 Figures Test) [14] were in the average lower range, although recognition performance was also impaired.

## Discussion

Cerebellar lesions are associated with dysfunctions of the contralateral cortical hemisphere, with right cerebellum damage often affecting verbal working and episodic

memory [15]. On top of these aspects of memory, in the patient reported here, the right cerebellar lesion was also accompanied by a marked impairment of source monitoring for verbal information while nonverbal learning and recall remained nearly unaffected.

These observations clinically illustrate the functional connectivity of the cerebellum with frontal and medio-temporal subregions mediating a specific aspect of human memory, the 'source memory'. Although considering the absence of functional imagery we are not able to establish which regions (more frontal or more medial temporal lobe) are underactive in our patient, this case makes a small but substantial contribution to the not yet comprehensive understanding of cerebellar-cortical networks.

As knowing about the when and where of learning is of considerable everyday relevance, careful neuropsychological assessment in cases with cerebellar lesions is important for medical and occupational rehabilitation.

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